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Differences in Selected Predictors of Anterior Cruciate Ligament Tears Between Male and Female NCAA Division I Collegiate Basketball Players

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Objective: To examine sex differences in strength, Q-angle, and pronation as predictors of anterior cruciate ligament (ACL) injuries.

Design and Setting: Height, weight, sum-of-seven skinfolds, quadriceps and hamstrings strength, Q-angle, and pronation were measured in each subject.

Subjects: Male (n = 23) and female (n = 25) NCAA Division I basketball players, all from the same institution and participating in identical conditioning programs.

Measurements: Strength was measured at $180°\cdot s^{-1}$ using an isokinetic dynamometer. Q-angle was assessed with the leg fully extended and flexed to 30°. Pronation was determined with the navicular drop test.

Results: A 2 × 2 factorial analysis of variance indicated significant differences in the eccentric hamstrings-to-eccentric quadriceps strength ratio (female right = 46.11% ± 2.83%, left = 52.73% ± 3.74%; male right = 89.08% ± 6.34%, left = 93.16% ± 9.14% (P < .001)) and Q-angle measured in 30° of flexion (female right = 13.37° ± 0.99°, left 15.56° ± 1.34°; male right = 5.62° ± 0.75°, left = 6.00° ± 0.86° (P = .05)).

Conclusions: The results of this investigation indicate that, of the variables thought to contribute to ACL injuries, eccentric hamstrings strength relative to concentric quadriceps strength and Q-angle measured in 30° of flexion appear to be significantly different in males and females.

Key Words: sex, knee, strength, Q-angle, navicular drop test

The anterior cruciate ligament (ACL) tear is the most common severe ligament injury occurring to the knee.[1] Female athletes appear to be at greater risk for this injury than males.[2-4] In the recent NCAA injury statistics,[5] women's basketball players were six times more likely to incur an ACL tear than their male counterparts. Sex differences that may account for this include anatomic considerations, as well as different levels of strength.[3,6-10] Two anatomic considerations given credence include pronation[8,11] and Q-angle.[8,9]

Strength of the quadriceps and hamstrings has been investigated with respect to its effect on knee stability.[12-17] More et al[14] suggested that the hamstrings act as a protagonist to the ACL by reducing anterior tibial translation and internal tibial rotation during flexion, thus functioning synergistically with the ACL to provide anterior knee stability.

While several studies have investigated different anatomic markers,[3,8,11] few have explored specific strength parameters such as strength-to-body mass ratios and eccentric and concentric strength ratios. Nor have comparisons been drawn regarding anatomic and strength indicators in uninjured male and female basketball players. The purpose of this investigation was to examine sex differences in strength, Q-angle, and pronation as predictors of ACL injuries in healthy collegiate male and female basketball players. By identifying some specific differences, we can begin to work toward preventive measures that may minimize this devastating injury in the female population.

METHODS

Subjects

Forty-eight male (n = 23) and female (n = 25) subjects participated in this investigation. All subjects were NCAA Division I basketball players from the same institution participating in identical conditioning programs. The study was approved by the Institutional Review Board's Human Subjects Committee. Before testing, all subjects read and signed an informed consent form.

Height, weight, and sum-of-seven skinfolds data were collected for each subject. Additionally, each subject participated in three tests: a strength test to assess quadriceps and hamstrings strength, a measurement of Q-angle, and an evaluation of pronation.

Strength Assessment

All subjects performed three trials of maximal knee extension and flexion on a 125E KinCom (Chattecx Corporation, Chattanooga, TN) isokinetic dynamometer. Gravity correction was performed before each test. Tests were conducted on each of the subjects' contralateral limbs at $180° \cdot s^{-1}$. Data were processed with custom software (Chattecx Corporation). Knee extension and flexion were measured with the subjects in the seated position and the dynamometer axis of rotation aligned with the knee's frontal axis. The total range of motion at the joint for extension approximated 90° and that for flexion approximated 120°. Subjects were allowed unlimited submaximal warm-ups until they felt comfortable with the mechanics of the movement. Warm-ups ranged from three to five trials with each motion. Each subject was then asked to perform three maximal concentric and eccentric quadriceps and hamstrings contractions. The mean force outputs from each leg were used to calculate the following ratios: left and right hamstrings strength to body mass, left and right concentric hamstrings to concentric quadriceps, left and right concentric hamstrings to eccentric quadriceps, and left and right eccentric hamstrings to eccentric quadriceps.

Q-Angle Measurement

Q-angle measurements were obtained with the knee in 30° of flexion and in complete extension as described by Arnheim and Prentice.[1] A line was drawn from the anterior-superior iliac spine so that it bisected the patella; a second line was then drawn from the midpoint of the patella to the tibial tubercle. The axis of a goniometer was placed at the intersection of the two lines, with one arm of the goniometer aligned along the anterior-superior iliac spine line and the second arm along the tibial tubercle line. The angle was then read from the scale.

Navicular Drop Test

The navicular drop test described by Brody[18] was performed on each subject to measure pronation objectively. This test involves locating and marking the navicular tuberosity of the foot. With the athlete seated and the knees flexed to approximately 90°, the subtalar joint was positioned in neutral. An index card was placed at the medial aspect of the foot, and the level of the navicular tubercle was marked. The athlete then assumed a full weightbearing position, allowing the foot to relax. The navicular level was noted on the card. The difference between the two marks was measured in millimeters. Q-angle and navicular drop were both measured bilaterally.

Data Analysis

Data were analyzed using a repeated-measures analysis of variance. An a priori level of significance of 0.05 was adopted.

RESULTS

Descriptive data for the two groups (males and females) are summarized in Table 1. Strength testing data, Q-angle measurements, and navicular drop results are presented in Tables 2 and 3. Examination of the strength data revealed a significant difference between groups for the eccentric hamstrings-to-eccentric quadriceps ratio bilaterally ($F_{1,46} = 7.23$, $P = .01$). However, no significant differences were noted for hamstrings strength-to-body mass ratios or concentric hamstrings-to-concentric quadriceps or eccentric hamstrings-to-concentric quadriceps ratios.

Similarly, significant differences between groups were observed for Q-angle when measured with the knee in 30° of flexion ($F_{1,46} = 4.02$, $P = .05$). These differences were also noted bilaterally. There were no significant differences found for Q-angle measured with the knee in extension or for navicular drop.

DISCUSSION

These results suggest that eccentric hamstrings strength relative to eccentric quadriceps strength and Q-angle measured at 30° of flexion are significantly different for healthy male and female NCAA Division I collegiate basketball players.

Aune et al [12] have reported that hamstrings contraction helps to resist anterior tibial shear force at 30° of flexion in rats, thus reducing the load on the ACL. This finding is supported by Durselen et al,[16] who used nine cadaveric knees to investigate the influence of the quadriceps and hamstrings on ligament strain during loaded knee flexion. Their data suggested that activation of the quadriceps muscle had the most pronounced effect on ACL strain, especially in angles greater than 70° of knee flexion. An earlier investigation by More et al[14] indicated that hamstrings contraction decreases anterior tibial translation and internal tibial rotation and reduces tension on the ACL between 15° and 45° of knee flexion. The hamstrings, therefore, act as protagonists to the ACL in controlling tibial movement. Baratta et al[13] and Osternig et al[15] concurred that the hamstrings are activated independently from the quadriceps

Table 1. Subject Characteristics (Mean ± Standard Error of the Mean)

	Male		Female	
Variable	M	SEM	M	SEM
Age (y)	19.75	± 0.25	19.63	± 0.41
Height (cm)	187.21	± 4.64	176.10	± 1.91
Weight (kg)	88.01	± 5.93	70.80	± 2.93
Sum-of-seven skinfolds (mm)	81.88	± 15.01	102.69	± 6.72

Table 2. Strength Values (Mean ± Standard Error of the Mean)

Variable	Male M	Male SEM	Female M	Female SEM
Hamstrings: body mass (%)				
Concentric				
Right	28.58	± 1.53	33.11	± 3.20
Left	37.46	± 3.46	56.21	± 3.41
Eccentric				
Right	40.96	± 2.26	42.71	± 2.99
Left	52.54	± 5.98	68.69	± 7.68
Hamstrings: quadriceps (%)				
Concentric: concentric				
Right	76.95	± 7.00	57.09	± 3.50
Left	89.10	± 5.97	69.16	± 2.02
Eccentric: concentric				
Right	105.75	± 5.34	73.82	± 2.93
Left	108.16	± 7.14	75.65	± 3.78
Eccentric: eccentric				
Right	89.08	± 6.34	46.11	± 2.83*
Left	93.16	± 9.14	52.73	± 3.74*

* Denotes significance at $P \leq .05$.

Table 3. Navicular Drop and Q-Angle Values (Mean ± Standard Error of the Mean)

	Male M	Male SEM	Female M	Female SEM
Navicular drop (mm)				
Right	8.87	± 1.81	7.31	± 0.75
Left	8.50	± 1.05	7.37	± 0.98
Q-Angle (°)				
Extension				
Right	5.36	± 0.86	10.06	± 0.99
Left	5.50	± 0.96	10.31	± 1.42
30° Flexion				
Right	5.63	± 0.75	13.38	± 0.99*
Left	6.00	± 0.87	15.56	± 1.34*

* Denotes significance at $P \leq .05$.

and aid in stabilizing the knee. Baratta et al[13] used three groups of healthy individuals, ranging from sedentary to highly trained athletes, to quantify the coactivation patterns of the knee flexor and extensor muscles in an effort to identify the role of antagonist muscles in maintaining joint stability. Their data supported the findings of other researchers, in that the hamstrings aid in deterring anterior tibial translation at approximately 40° of extension. Additionally, Baratta et al[13] suggested that an individual with hypertrophied quadriceps without complementary hamstrings strength is predisposed to an ACL injury. Similarly, Osternig et al[15] investigated coactivation patterns and ACL dysfunction and reported that the hamstrings generated the greatest activity during maximal knee extension.

A landing/deceleration maneuver has been proposed as an activity that commonly causes ACL injuries.[19] Boden and Garrett[19] interviewed 40 athletes about the events surrounding their injuries and found that 1) 62% were noncontact injuries; 2) the average angle of knee flexion at the time of injury was 20°; and 3) 19% of the injuries occurred while performing a deceleration/landing maneuver. For the transition from running to jumping or a stance position to occur safely, the athlete must have good control of muscular activity. During landing/deceleration activities, flexion moments are occurring at the knee and hip. At the same time, the quadriceps and hamstrings are contracting eccentrically to decelerate the horizontal velocity of the body.[17] According to Palmitier et al,[17] the hamstrings contract eccentrically to stabilize the hip, while the quadriceps contract eccentrically to stabilize the knee. Activity in the hamstrings muscle, induced for hip stability, helps neutralize the tendency of the quadriceps to cause anterior tibial translation.[17] When the stabilizing influence of muscle is not present, inert internal tissues, such as ligaments, cartilage, and bone, become more vulnerable. Therefore, a deficit in eccentric hamstrings strength relative to eccentric quadriceps strength could predispose an athlete to an ACL injury.

Significant differences between groups were also noted for Q-angle when measured with the knee in 30° of flexion ($P <$ .05), with the males exhibiting smaller angles than the females.

Xerogeannes et al[20] found that the greatest magnitudes of force were incurred by the ACL at 30° of knee flexion. Q-angle is often associated with increased tibial internal rotation.[21] The ACL functions to prevent internal tibial rotation; thus, at 30° of flexion, if internal rotation is increased in females and the eccentric hamstrings-to-eccentric quadriceps strength ratio is diminished, during deceleration the knee is incurring two forces that compromise the integrity of the ACL and is lacking in one restraint mechanism. The combination of structure and strength may predispose females to a greater incidence of ACL injuries. Further research investigating landing mechanics and possible strengthening techniques to address eccentric hamstrings deficits is warranted. Additionally, longitudinal data regarding these variables as reliable predictors are needed.

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